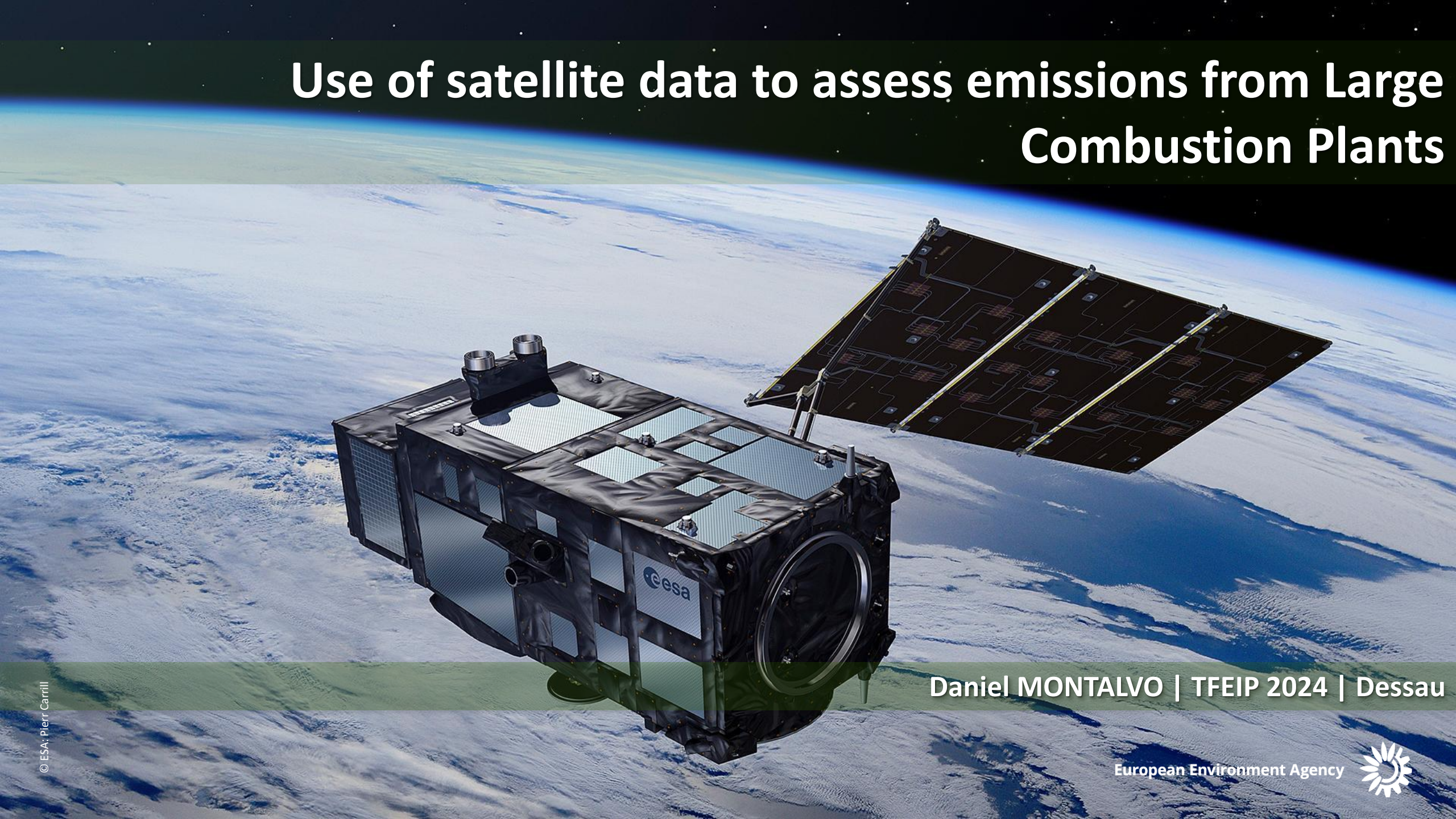
Use of satellite data to assess emissions from Large Combustion Plants



Daniel MONTALVO | TFEIP 2024 | Dessau

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Intentions behind this work

- Build an independent view around the **maturity of satellite-derived emissions** in the context of large-point source inventories

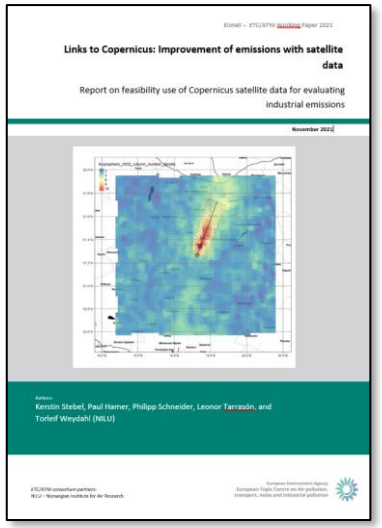
- Understand **skills** required**, budget** scales and **practicalities** of the method

- Stress progressively the method to understand whether it could work at scale

The sequence we followed

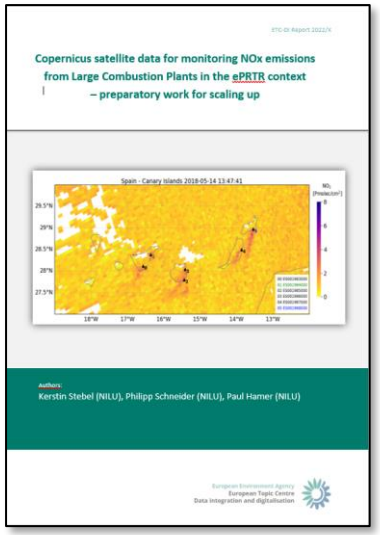
2021 Small Case Study

- 12 LCPs
- Model set-up



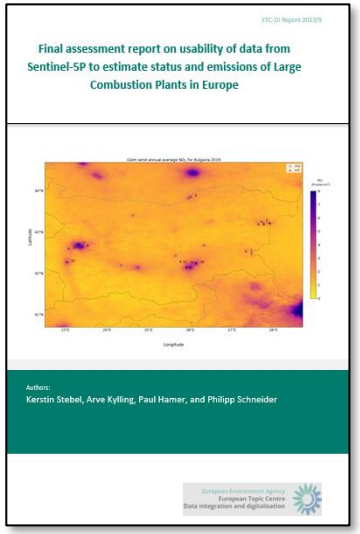
2022 Extensive analysis

- Wider number of LCPs
- Sensitivity
- Scope full-scale implementation

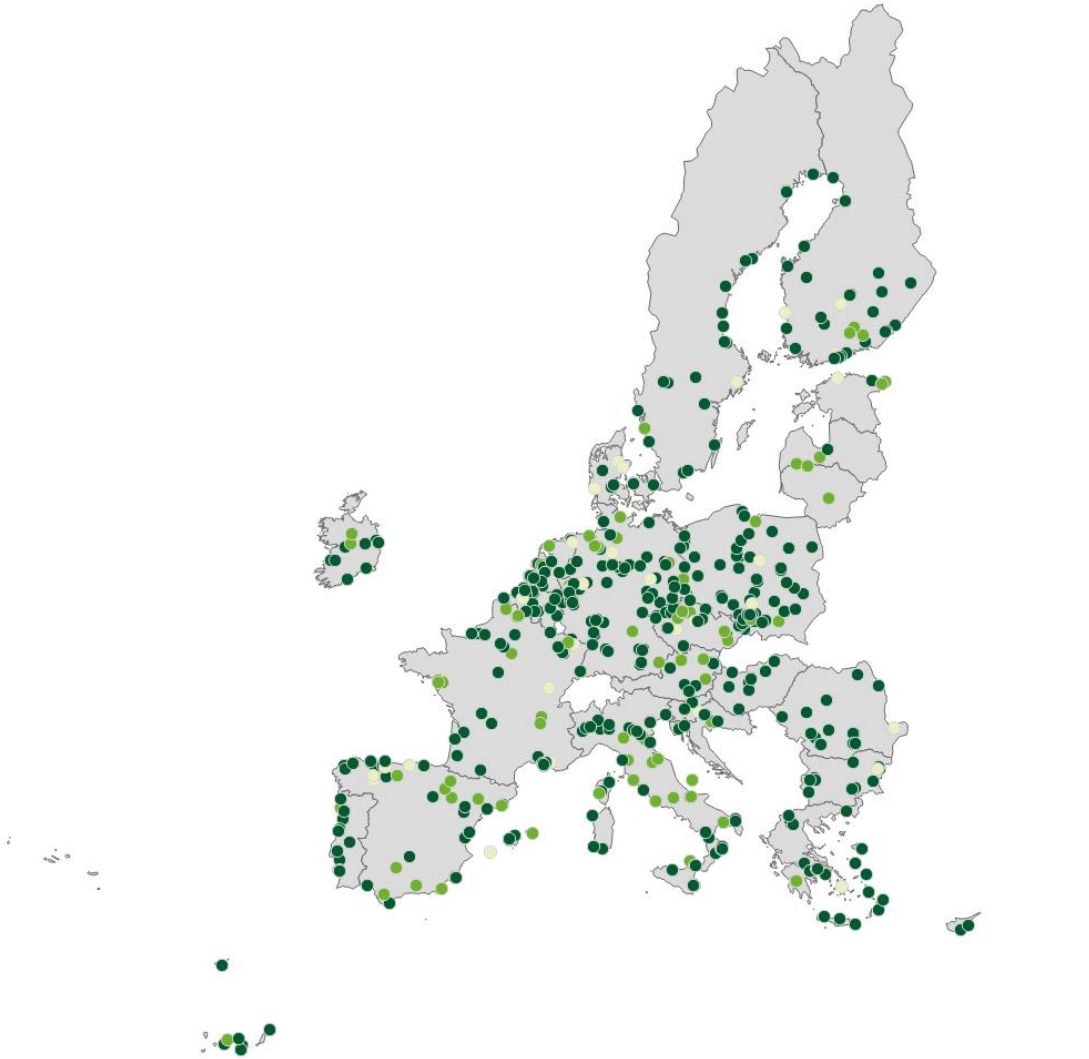


2023 Implementation at scale

- Test all possible scope
- Use case 1 - QA input to reporting data validation
- Use case 2 - Gap-filling of late or not reported dataset



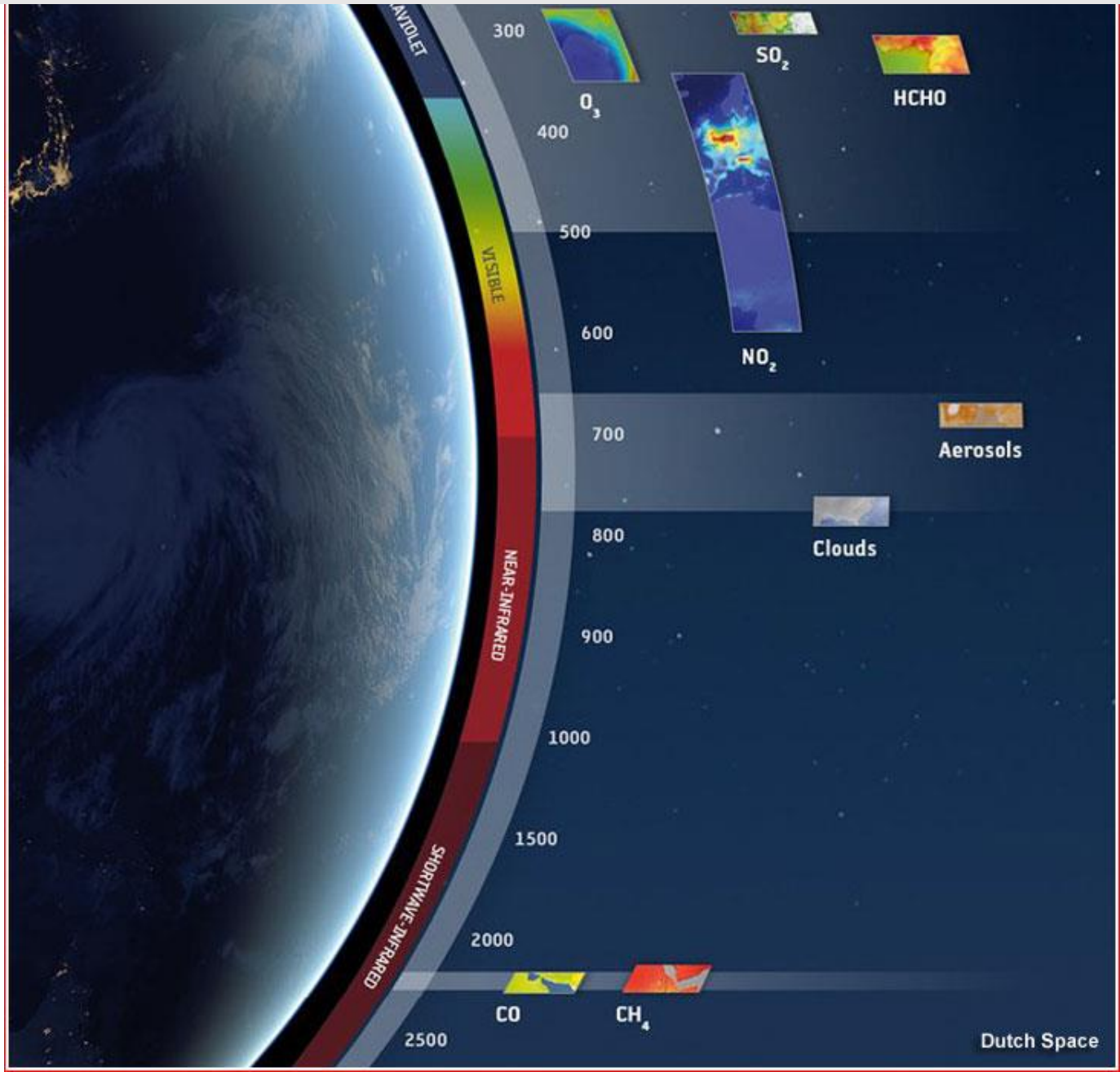
Scope of the study



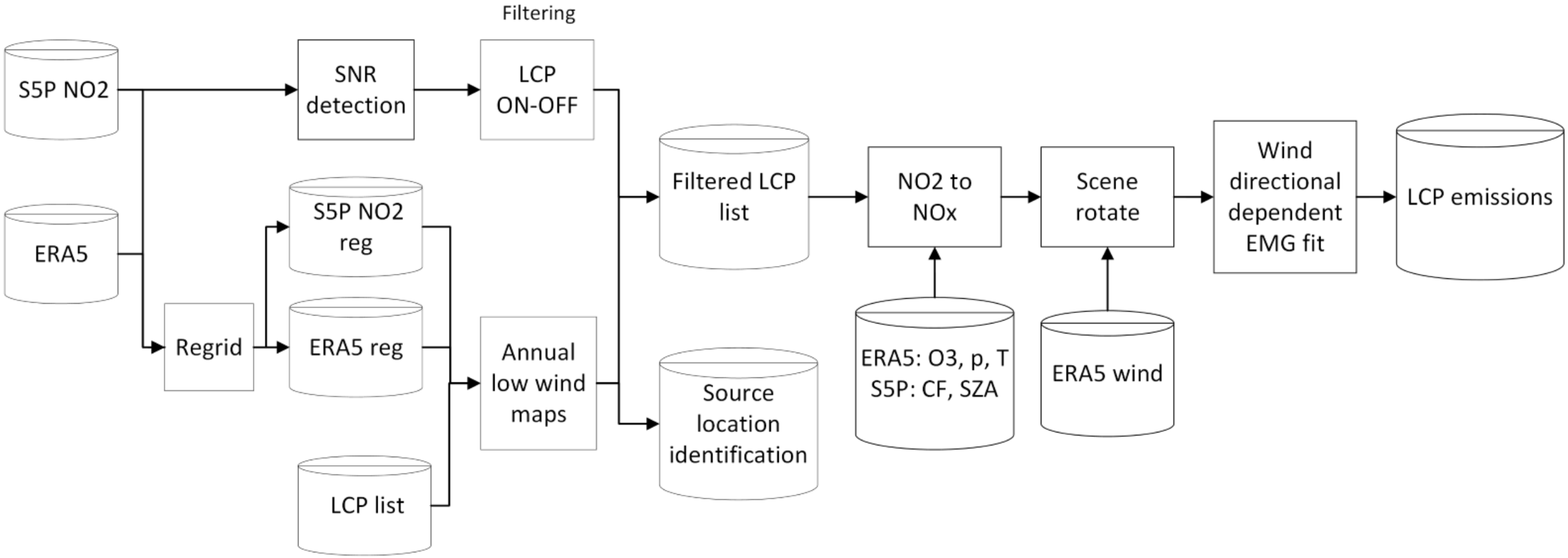
- Geography: **all Europe**, including remote locations
- Sources: **NOx > 250 tonnes/year**
  - 607 facilities in scope
  - Traditional method covers roughly 4000
- Time period: **May 2018 – December 2022**
- Tool: **Sentinel-5P**
  - Data are free to use
  - Some pre-processing is increasingly available
  - Reasonable expectation of continuity

TROPOspheric Monitoring Instrument (TROPOMI) on the Sentinel-5 Precursor (S-5P) satellite

- Launched on 13th October, 2017
- Sun-synchronous orbit at 824 km altitude
- Initial pixel size of 7 km x 3.5 km at nadir
- Reduced to **5.5 km x 3.5 km** on 6th August 2019
- Equator crossing time at around 13:30 LT (ascending node)
- Across-track swath width 2600 km, thus obtaining **daily global coverage**



Method dependent of several data sources, complex sequence

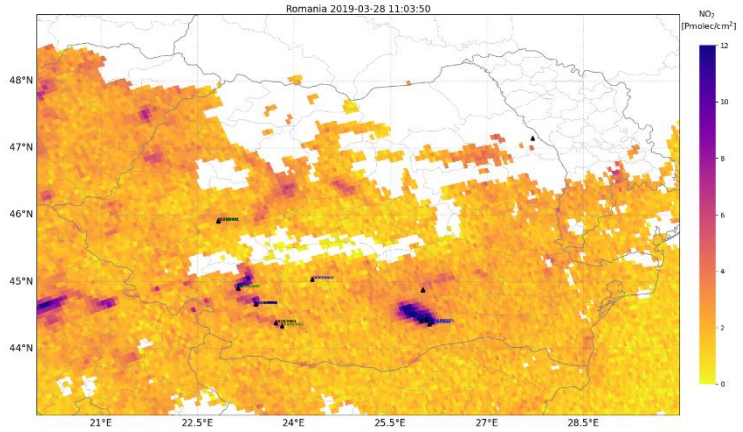


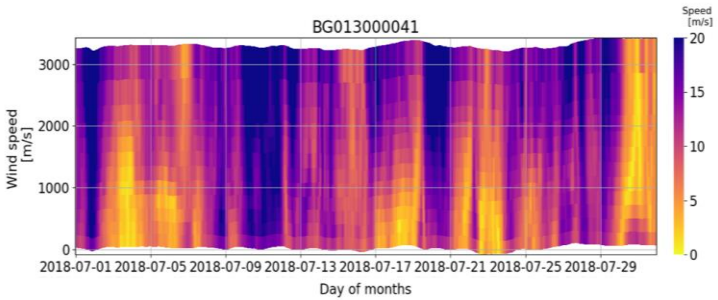
Main input data

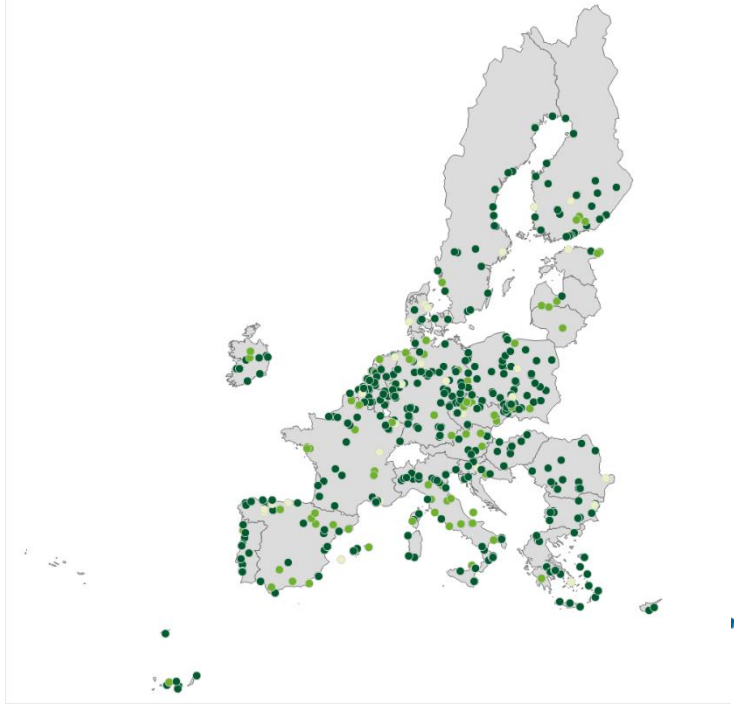
TROPOMI NO2

ERA5 meteorological data from ECMWF

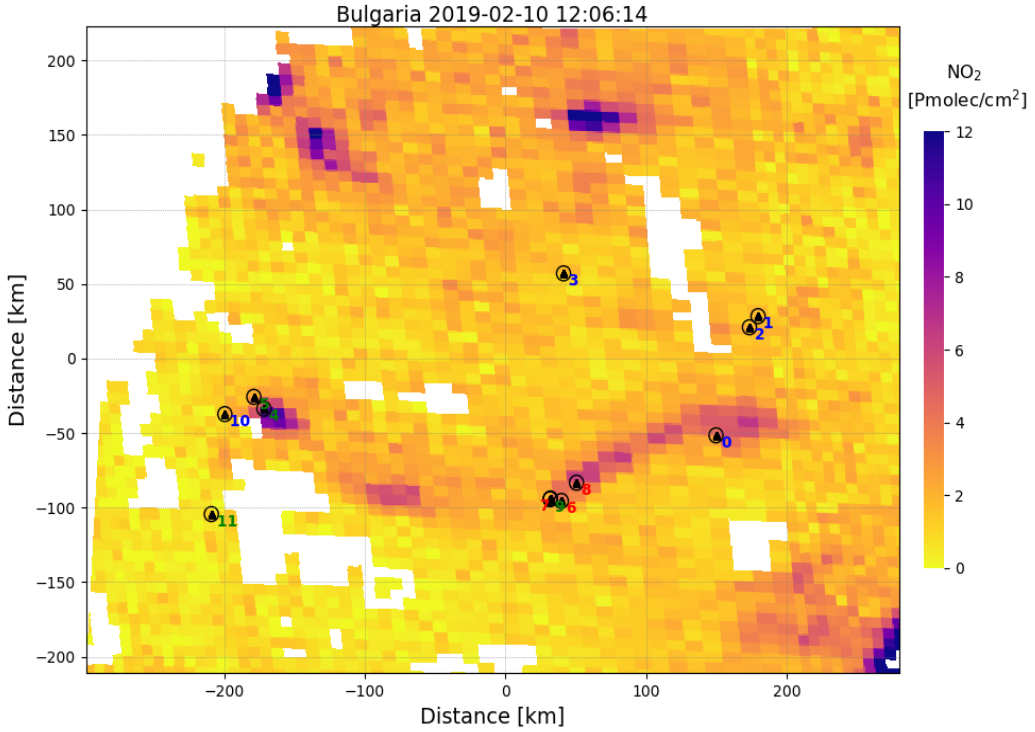
Coordinates of emission sources from EEA Database

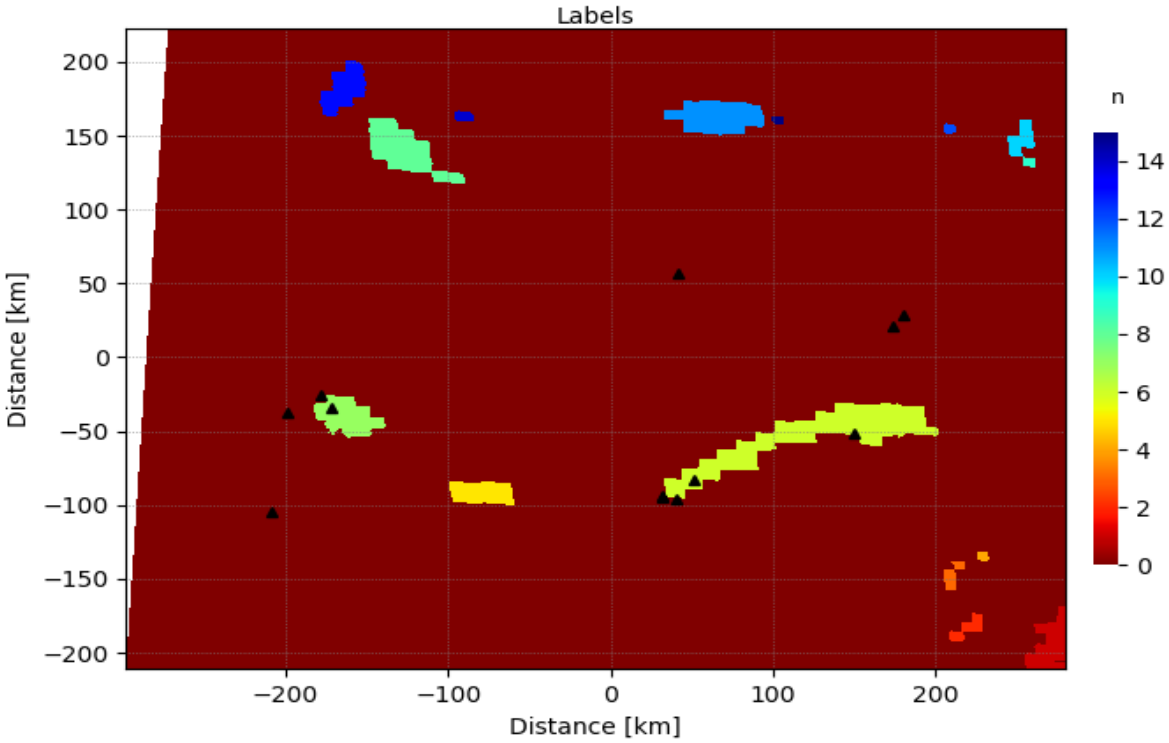






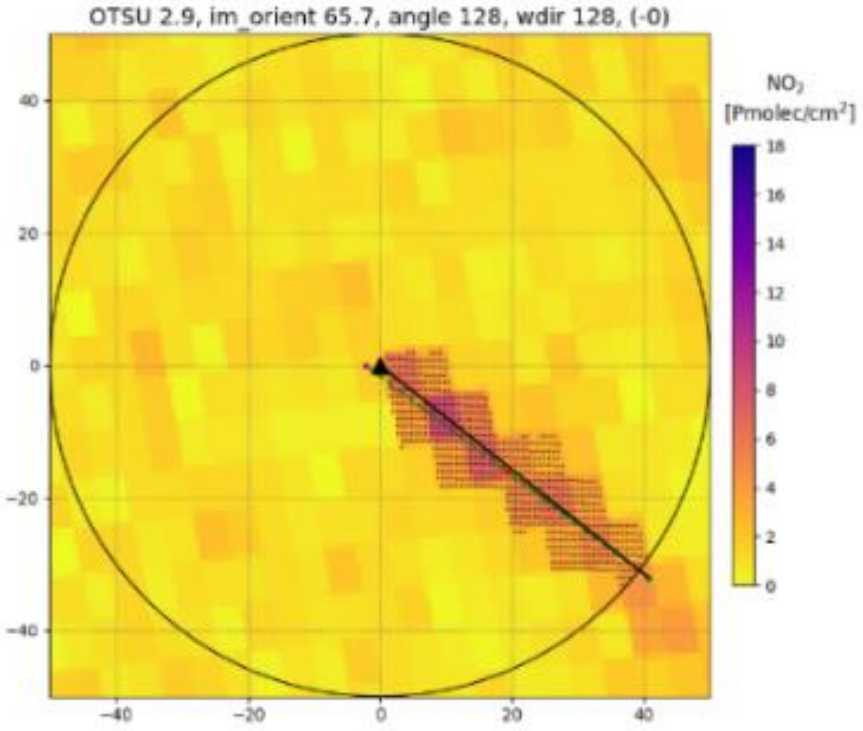
Plume detection



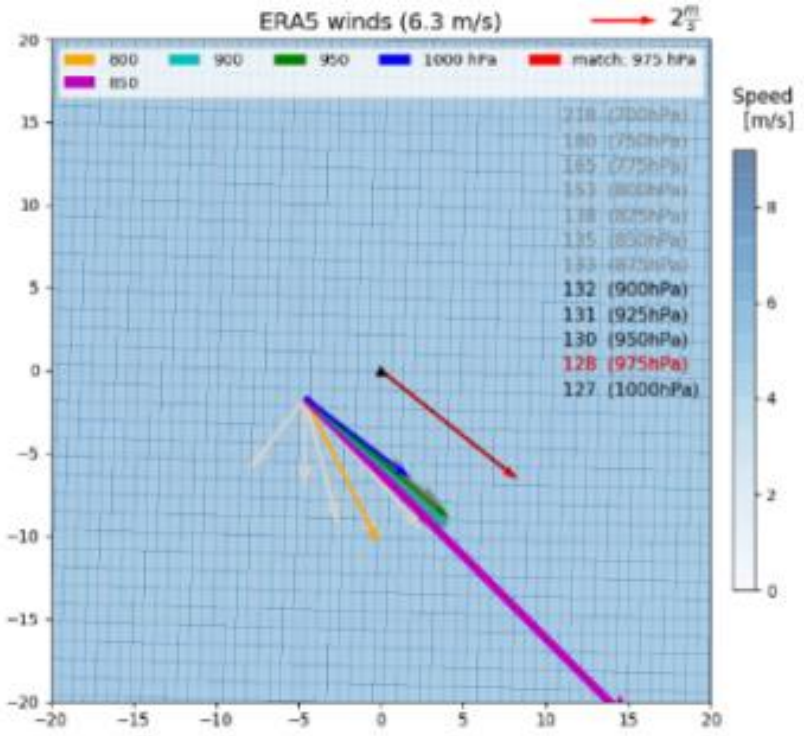


Example of plume detection and plume sequencing for a single overpass over Bulgaria. The left panel shows the NO_2 observations and the location of the different facilities (color code represents emissions below 0.5 kt (blue), between 0.5 – 1 kt (green) and above 1 kt (red)). The right panel shows the plume segmentation

Determining of plume in relation to the direction of winds



TROPOMI NO_2 plume (20 km circle around LCP site)



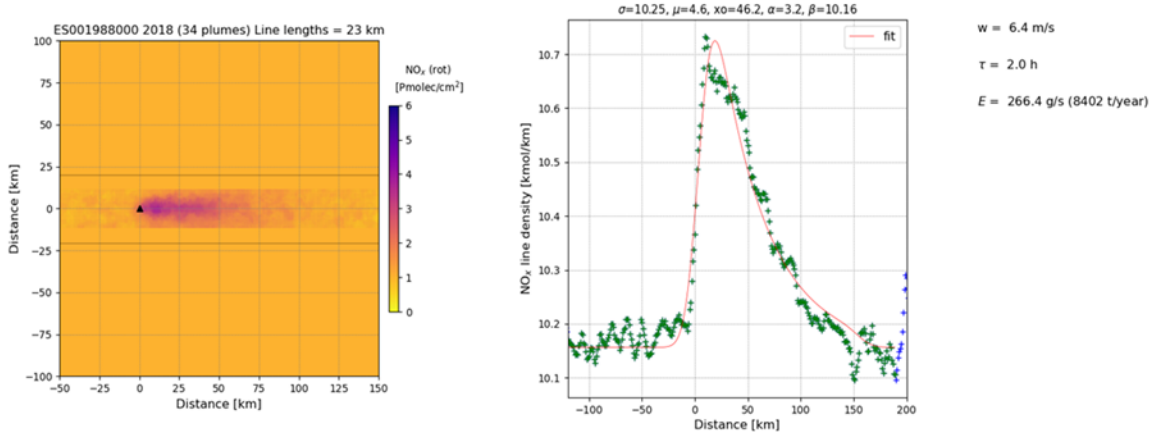
ECMWF winds at different pressure levels

Determination of pressure level (ERA5 winds and O_3) to be used for the NO_2 to NO_x conversion and wind-speed for the emission estimates.

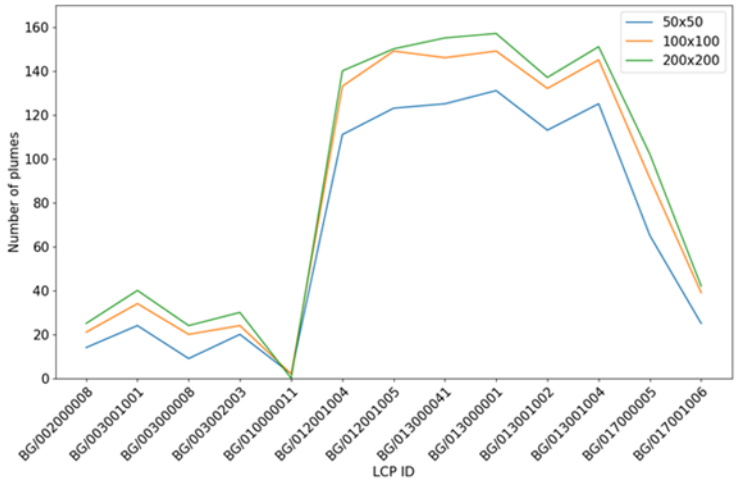
A series of additional refinements and checks were needed

Conversion to NOx and TROPOMI line density

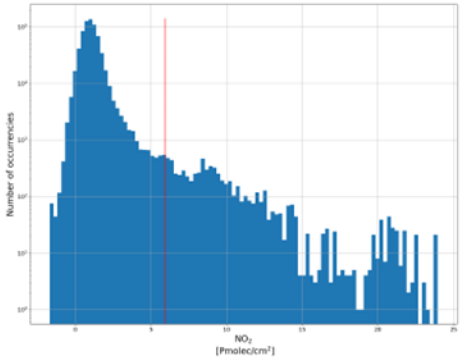
TROPOMI NO_2 line density (S)



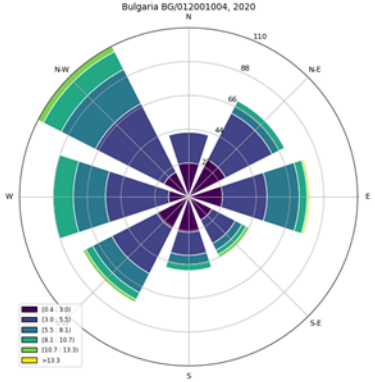
Sensitivity analysis
determining the right pixel side



Distinguishing noise and signal

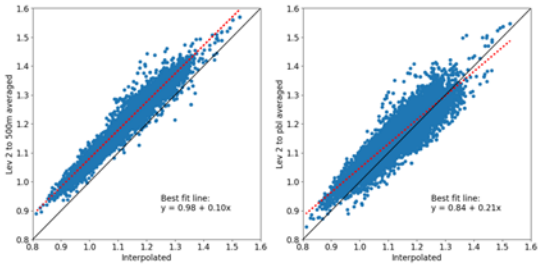


Considering the effect of wind



- Speeds
- Directions
- Vertical variation

Chemistry in the atmosphere



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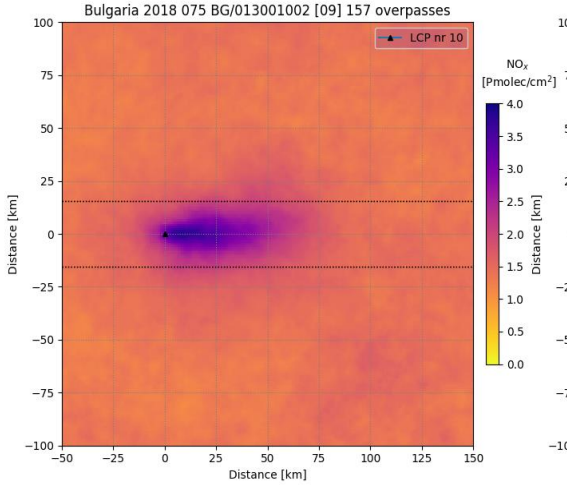
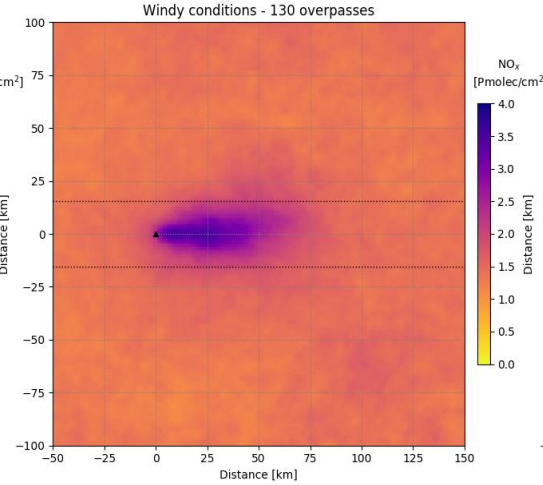
To finally proceed with the final emission estimate

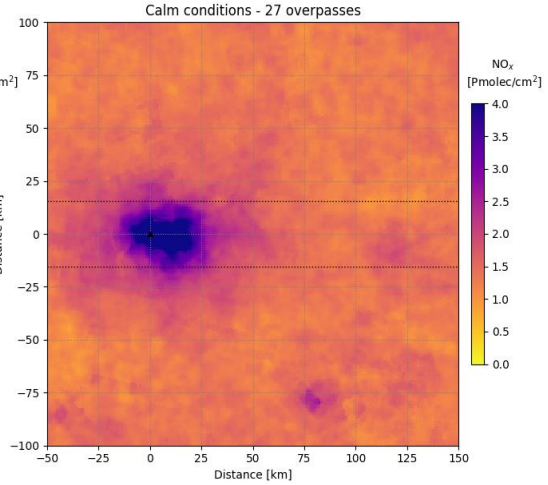
General case

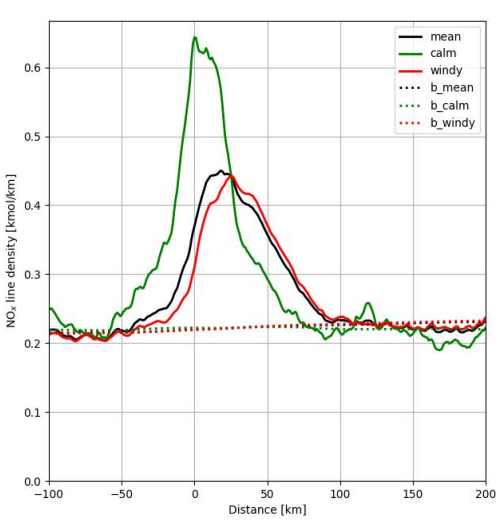


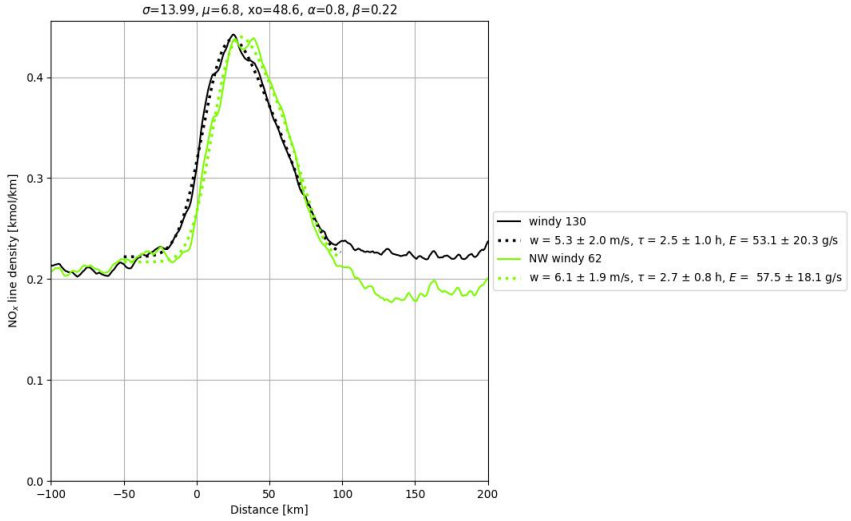
Windy day



Very calm







Determination of NOx follows the method named “Exponentially Modified Gaussian fit”

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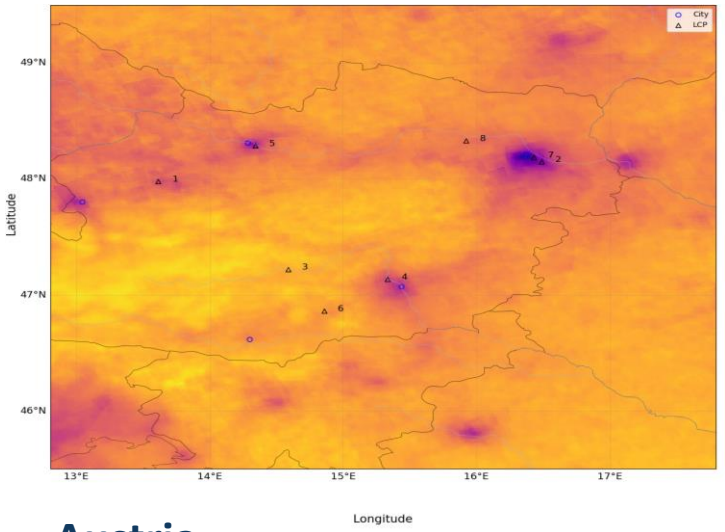
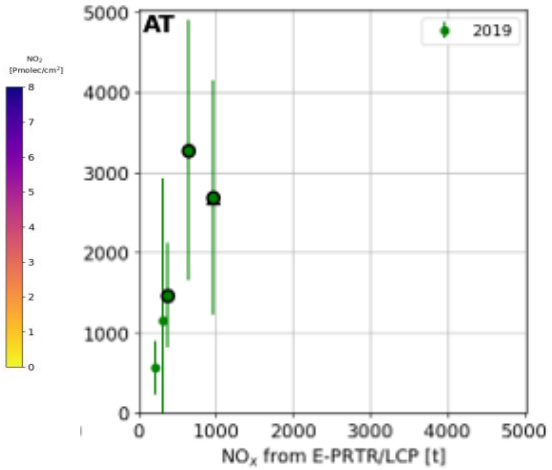
How did the results look like?



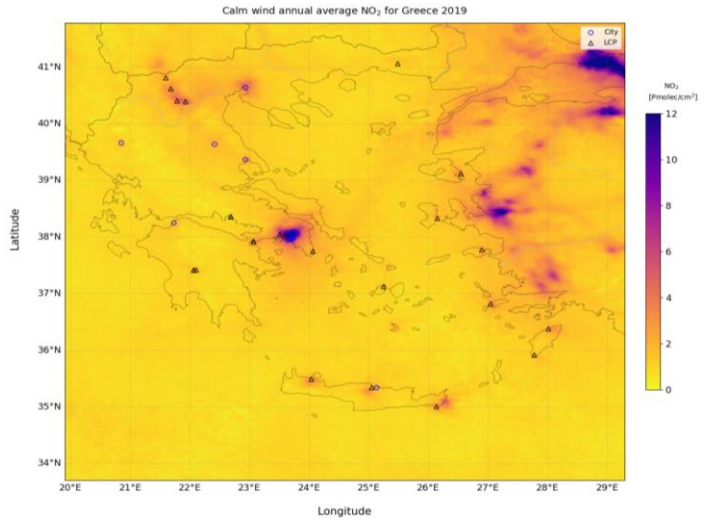
Austria



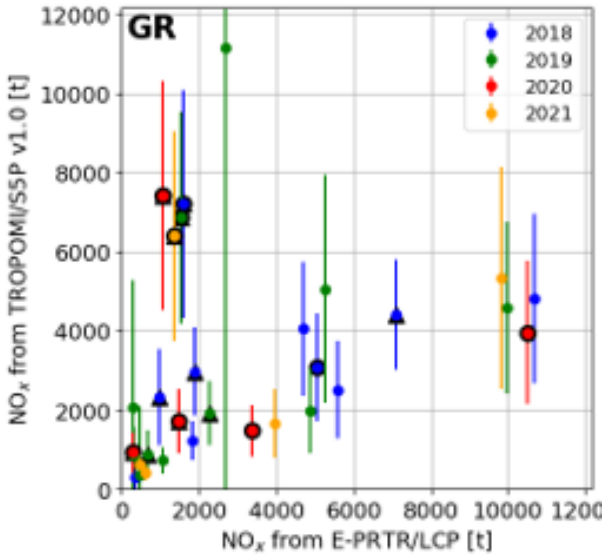
Results for 2019

	Estimated	Reported
Plant	2019	2019
AT/9008390705353	-	677
AT/9008390661741	**2687 (54%)**	**964**
AT/9008390614785	-	446
AT/9008390537091	**3280 (49%)**	**636**
AT/9008390731697	**1470 (44%)**	**372**
AT/9008390973059	**1157 (153%)**	**305**
AT/9008390972489	-	434
AT/9008390975220	**568 (59%)**	**215**

The method shows a pattern of over-estimating emissions



Greece



Results for all years

The method offered very reasonable results

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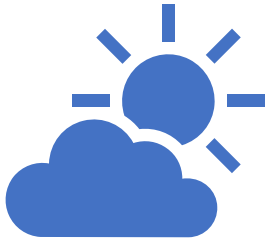
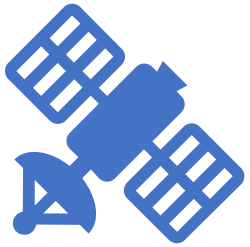
Which factors undermined the method the most?

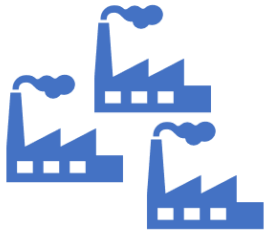
Proximity to cities



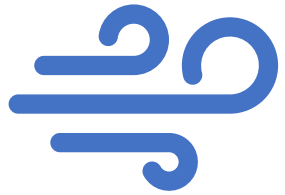
Cloud coverage



Available resolution

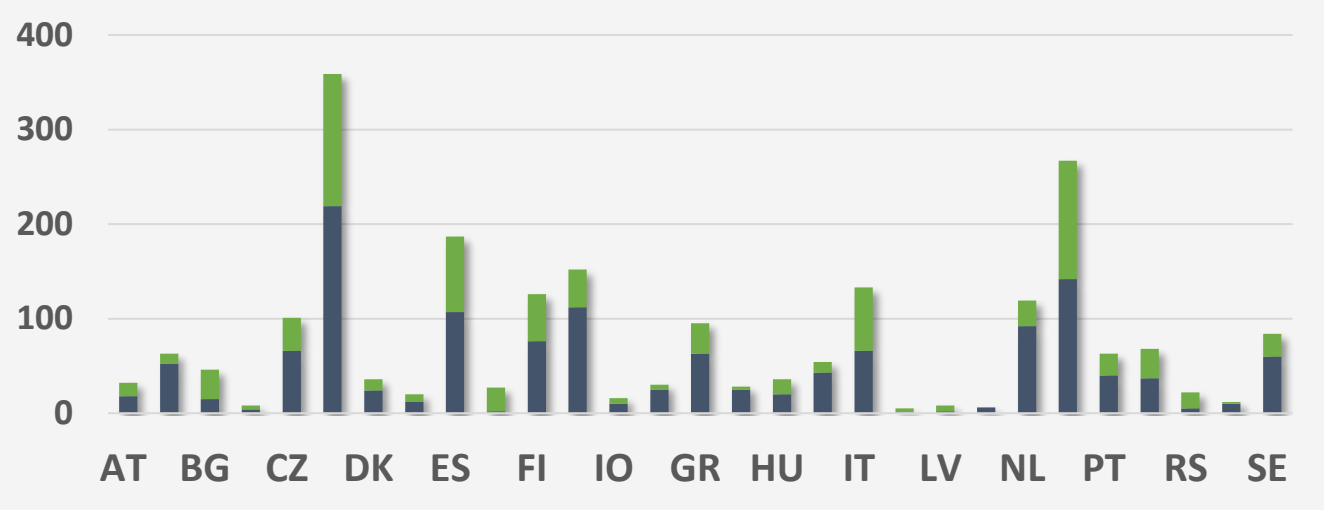


Accumulation of emission sources



Strong winds

How successful was the method in delivering results?



Globally, just 35% of total target of sites returned a value

- LV and BG highest coverage (75%, 60%)
- HR, BE and SI lowest coverage (11-17%)

In general, the estimates where either comparable to reported emissions or larger (most prevalent)

Positive findings

- Possibility of using a **single instrument for all Europe is** key to have robust assessment
- The input data is readily available, **cost-free** and increasingly pre-processed
- The topic is very dynamic with new science being developed constantly
- The limitations of the instrument used are likely to be reduced significantly with the launch of **additional instruments** as part of the Copernicus Programme

Limits identified

- **Detection threshold is very high**: 250 tonnes NOx per year
- Just **35% of the reported points above the threshold have been assessed**
- **Background NOx pollution level** is a key limiting factor to identify clear point sources
- **Big cities proximity** prevent from assessing point sources
- **Meteorogical condition** (cloud coverage and image contrast) is a limiting factor
- Human intervention is still very substantial and processing time long
- Costs for a very small exercise were high
- **Skills required are scarce in our organisation**

Overall conclusions

- **The future is getting closer**
  - The technique has the potential to be used for quality assurance in a first instance and possibly to replace other methods subsequently
- **But is not yet ready**
  - Limitations and costs make it unfeasible for EEA at this point
- A systematic **revisiting** of the technique is advisable
- **Earth observation literacy** is a good skill to look for institutions involved in inventory compilation

Thank you

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